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Investigating and Analysis of Thermal Energy Storage System Using $MgCl_2.6H_2O$ PCM for the Application of Refrigeration

E. Jagadeesan[1], K.B. Yogeshwaran[2], C. Manikandan[3]
[1]PG Scholar, [2]Assistant Professor, [3]PG Scholar, Department of Mechanical Engineering
Adhiparasakthi Engineering College, Melmaruvathur, Tamilnadu, India.

Abstract—In this paper we are mainly considering the hot and cold temperature interrelation in the analysis of thermal energy storage. The solidification of the storage system is increased by adding the hydrated salts. The phase change material has high latent heat storage density, which helps to store the energy. Hydrated salts have high volumetric storage density relatively with high thermal conductivity; also its cost is less when compared to the paraffin waxes. The high storage density of salt hydrate materials is difficult to maintain and usually decreases with the cycling. The salts such as $MgCl_2.6H_2O$and water is mixed in the correct proportions to intimate the change temperature in the material. The changes make the food preservation and environmental cooling and to save the renewable energy resources, by using this technique the cooling will stands for longer period and much more energy can be saved.
Keywords— Phase change material, Thermal energy storage, Inorganic material, Latent heat storage, Hydrated salts.

I. INTRODUCTION

The use of renewable energy sources and increased energy efficiency are the main strategies to achieve better thermal energy storage. In both strategies, heat and cold storage will play an important role. Refrigerators, space heating, and domestic ho t water are a part of every household. Thermal energy storage (TES), which is heat and cold storage, plays an important role in many energy systems, not only households but also industrial processes. Even though storage itself will never save energy, it is often able to improve a system in a way that it is more energy or cost efficient. Thermal energy can be stored in the form of sensible heat in which the temperature of the storage material varies with the amount of energy stored. Water or rock can be the best example.

Alternatively, thermal energy can be stored as latent heat in which energy is stored when a substance changes from one phase to another by either melting or freezing. Thus the temperature of the substance remains constant during phase *change*. The energy used can have different sources, which are renewable and non-renewable. Especially solar energy is not continuous and thus heat storage is necessary to supply heat reliably. When solar collectors are used to heat domestic hot water, the storage also matches the different powers of the solar collector field, which collects the energy over many hours of the day, to meet the demand of a hot bath that is filled in only several minutes. Sensible heat storage is used for example in hot water heat storages or in the floor structure in under floor heating.

An alternative method is changing the phase of a material. The best -known examples are ice and snow storage. The storage of thermal energy in the form of latent heat in phase change materials (PCMs) represents an attractive option for low and medium temperature range energy applications. Wide ranges of PCMs have been investigated, such as paraffin wax, salt hydrates and non - paraffin organic compounds. The economic feasibility of employing a latent heat storage material in a system dep ends on the life span and cost of the storage materials. In other words, there should not be major changes in the melting point and the latent heat of fusion with time, due to thermal cycles of the storage materials. For latent heat storage, commercial grade PCMs is preferred due to various reasons, such as low cost and easy availability.

A. Thermal energy storage

Thermal energy storage (TES), also commonly called heat and cold storage, allows the storage of heat or cold to be used later. To be able to retrieve the heat or cold after some time, the method of storage needs to be reversible. Sensible heat by far the most common way of thermal energy storage is as sensible heat. The phase changes solid-liquid by melting and solidification can store large amounts of heat or cold.

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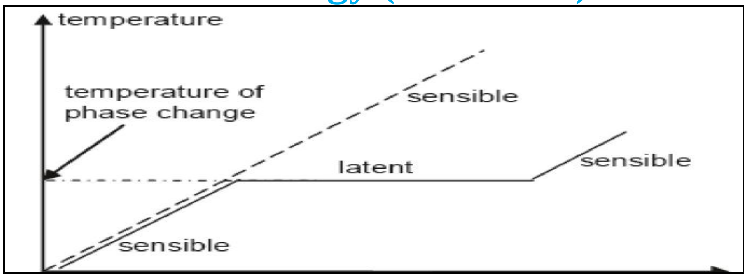

Fig 1. Latent and sensible heat

B. Phase change material

Phase change material (PCM) is very attractive because of its high storage density with small temperature swing. It has been demonstrated that for the development of a latent heat storage system in a building fabric, the choice of PCM plays an important role in addition to heat transfer mechanism in the PCM. Inorganic phase changes of materials are a perspective way of thermal energy storage. Big latent heat, good thermal conductivity and inflammability are the main advantages of inorganic materials. But they cause corrosion and suffer from loss of H_2O. Incongruent melting and super cooling are the biggest problem with their exploitation. During melting and freezing there are precipitations of other phases which do not take part in next process of charging and discharging. High latent heat of fusion per unit mass, so that a lesser amount of material stores a given amount of energy. High specific heat that provides additional sensible heat storage effect and also avoid sub cooling. High thermal conductivity so that the temperature gradient required for charging the storage material is small.

C. Selection criteria for PCM

1) Thermal properties:
   a) Suitable phase-transition temperature.
   b) High latent heat of transition.
   c) Good heat transfer.

2) Physical properties:
   a) Favourable phase equilibrium.
   b) High density

3) Kinetic properties:
   a) No supercooling.
   b) Sufficient crystallization rate.

II. LITERATURE REVIEW

Pawan R. Ingole et al., Phase-change material (PCM) is a substance with a high heat of fusion which, on melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. PCMs are regarded as a possible solution for reducing theenergy consumption of buildings. For raising the building inertia and stabilizing the indoor climate, PCMs are more useful because of itsnature of storing and releasing heat within a certain temperature range. In this paper, recent developmentin the field of using different types of PCMs with concrete, their incorporation and the influence of PCMs on the properties of concrete at the different stages are reviewed.

Ming Liu et al., In the present study, a new Phase Change Material (PCM-34) was developed for the application of maintaining low temperature in a refrigerated truck. It offers opportunities in the field of thermal storage at the temperature of -34 °C. The melting and freezing characteristics of the new material have been examined experimentally using an Environmental Test Chamber. To reduces upper cooling, sixteen chemicals have been investigated as nucleating agents and three were found suitable. The successful development of PCM-34 has led to an innovative cooling system with an on-vehicle latent heat thermal storage system and an off-vehicle refrigeration unit. With the phase change storage system, the performance of the whole cooling system will be improved and the greenhouse gas emission will be drastically reduced compared with systems current in use.

MD. MansoorAhamedet al., Many agricultural commodities and food commodities are being kept in commercial cold storages. Problems associated with these cold storages are during power cuts for cold storage leads to an increase in temperature and can result in the loss in quality and value of stored products. This paper proposes the use of a passive system integrated into the walls of the cold storage facility to limit the rise in temperature due to power loss. Hence useful for commercial establishments as presently there are frequent power cuts.

DaolinGaoet al., Using phase change materials (PCMs) to store and release latent heat is essential to develop the renewable energy, improve the energy efficiency and relieve the conflict of energy between supply and demand. The aim of this study is to prepare novel inorganic PCMs for thermal energy storage with phase change temperatures at room temperature (18-25ºC), middle temperature (40-50ºC) and medium-high temperature (60-80ºC). In this chapter, on the basis of a brief introduction for the basic principle of PCMs and the progress on the available thermal energy storage technology, authors mainly focused on our newest research results on preparations and thermal chemical properties on magnesium nitrate hexahydrate as a basic substance and calcium chloride solution, ammonium nitrate or lithium nitrate as additions to modulate the phase change temperatures. After a series of thermal stability, supercooling, phase separating and recycle application studies, three kinds of PCMs were successful established.

GEERT-JAN WITKAMP et al., Crystal growth of$Mgcl_2$aqueous solution on a cooled surface has been studied theoretically and experimentally. The excess entropy production rate for heat and mass transport into, out of, and across the interface was used to define the fluxesand forces of the system. The method describes the interface as a separate (two-dimensional) phase in local equilibrium. Coupledheat and mass flux equations from non-equilibrium thermodynamics were defined for crystal growth and the temperature jump atthe interface of the growing crystal. All interface transfer resistivity's was determined using $Mgcl_2$ ·6H2O crystallization on acooled surface as an example case. The coupling coefficient showed that between 20 and 30% of the enthalpy of crystallization isreturned to the liquid side during crystal growth. The coupling of heat and mass transport equations at the liquid-solid interface.

III. EXPERIMENTAL SETUP

The experiments consist deep freezer at the centre of the deep freezer a sphere is filled with PCM. The temperature of the fluid can be varied between - 25 to 50°C.Constant wall temperature of the cylinder can be maintained during the experiment through the circulation of the external fluid from the constant temperature bath. PCM chosen for the experiment mixtures are 20%$Mgcl_2$+80%H_2O, 25%$Mgcl_2$+75%H_2O and 30%$Mgcl_2$+70%H_2O mixture, claimed to be suitable for cool thermal energy storage.

A. Deep freezer(REF)
B. Spherical ball filled with PCM
C. PCM temperature indicator
D. Stop watch (or)Clock

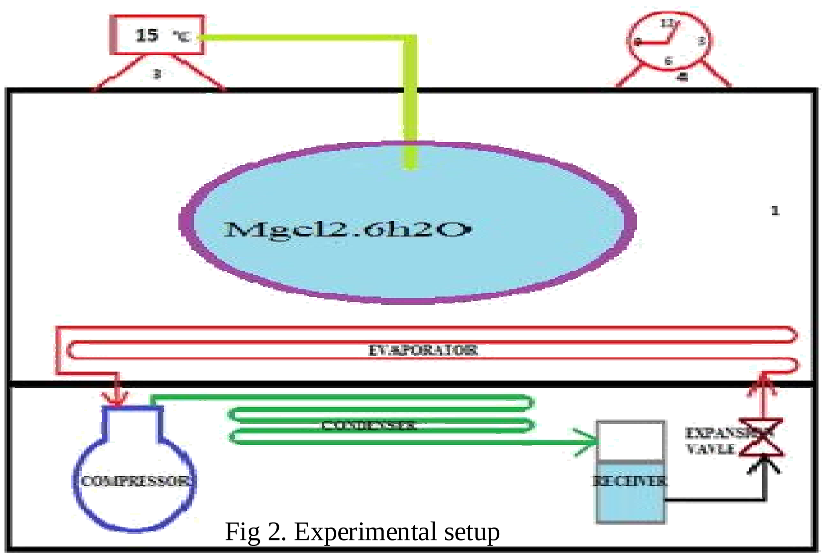

Fig 2. Experimental setup

This setup is used to determine the solidification and melting time of the phase change material.

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IV. RESULTS

The graph shows that, when time increases, correspondingly temperature will start to increase initially. For a certain time period, there will be a constant value in temperature. The constant value will be suddenly tending to increase, due to increase in time and there will be gradual increase in temperature. Again, the temperature will start to decrease and attains a constant temperature, even there will be an increase in time. Then, there will be gradual decrease in temperature.

FREEZING TEMPERATURE MEASUREMENTS		THAWING TEMPERATURE MEASUREMENTS	
Time(min)	Temperature (^oC)	Time(min)	Temperature(^oC)
0	30.5	0	-8.1
30	29.6	15	-8.1
60	25.2	30	-7.9
90	23.7	45	-7.5
120	16.5	60	-6.8
150	13.2	75	-6
180	11	90	-5.8
210	8.2	105	-4.7
240	5.4	120	-3.8
270	2.3	135	-2.9
300	1.2	150	-1.2
330	-0.4	165	-0.3
360	-1.2	180	1.3
390	-2.1	195	2.6
420	-3.5	210	4.2
450	-4.5	225	5.1
480	-5.8	240	6.4
510	-6.1	255	7.5
540	-8.6	270	8.3
570	-10	285	10.1

Table 1. Freezing and Thawing Temperature measurements for 70%water+30%salt

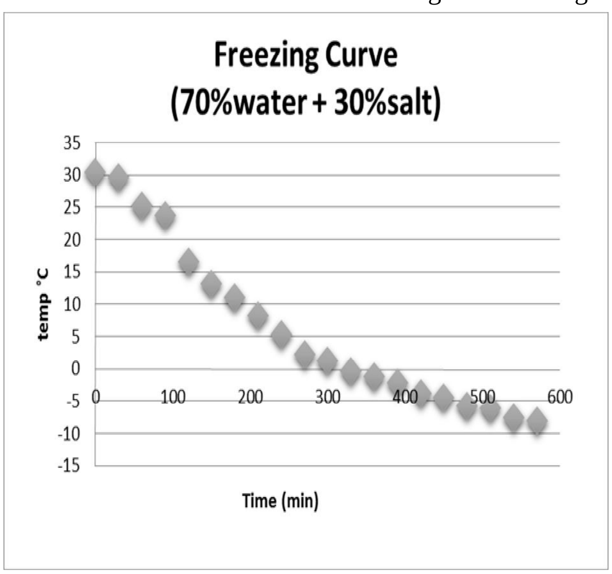

Fig 3. Freezing curve for 70%water+30%salt

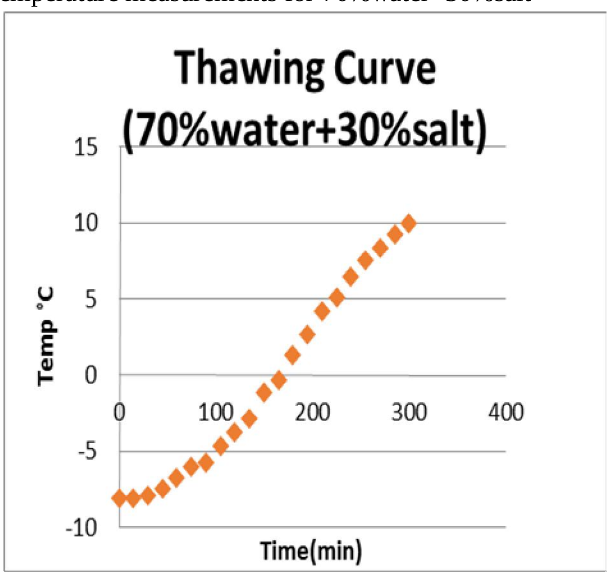

Fig 4. Thawing curve for 70%water+30%salt

From the above graph we conclude that for freezing experiment when the time increases the temperature decreases slowly and to

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attain the constant temperature for the certain period of time and the temperature is decreases slowly.

FREEZING TEMPERATURE MEASUREMENTS		THAWING TEMPERATURE MEASUREMENTS	
Time(min)	Temperature (^oC)	Time(min)	Temperature(^oC)
0	30.5	0	-10
30	28.9	15	-10
60	24.1	30	-8.5
90	20.4	45	-7.8
120	17	60	-6.3
150	15	75	-5.6
180	13.1	90	-4.2
210	10.1	105	-3.1
240	8	120	-2.6
270	5.2	135	-1.9
300	3.3	150	-1.1
330	1.1	165	-0.4
360	-0.4	180	0.5
390	-1.2	195	1.5
420	-3	210	3.1
450	-3.9	225	4.9
480	-4.8	240	6.1
510	-5.8	255	7.3
540	-6.9	270	8.1
570	-8.6	285	9.3
600	-10.1	300	10

Table 1. Freezing and Thawing Temperature measurements for 75%water+25%salt

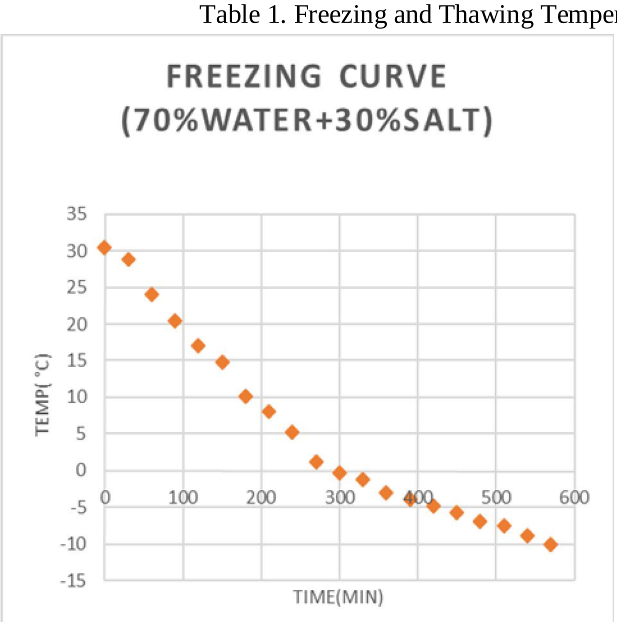

Fig 3. Freezing curve for 75%water+25%salt

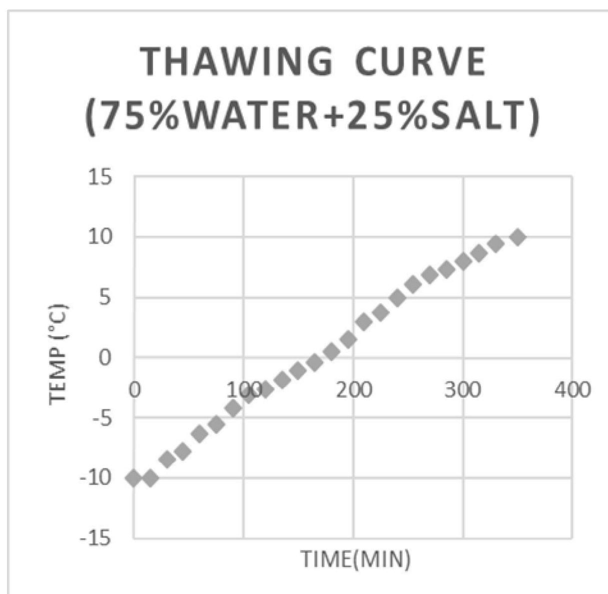

Fig 4. Thawing curve for 75%water+25%salt

For the first mixture the water content is taken as 70% and salt content is 30%, in the second mixture salt content is decreased by 5% and water content is increased by 5% to observe the temperature variation in the mixture constantly and the results can be

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plotted to obtain the best mixture.

FREEZING TEMPERATURE MEASUREMENTS		THAWING TEMPERATURE MEASUREMENTS	
Time(min)	Temperature (^{o}C)	Time(min)	Temperature(^{o}C)
0	30.5	0	-10
30	28.9	15	-10
60	24.1	30	-8.5
90	20.4	45	-7.8
120	17	60	-6.3
150	15	75	-5.6
180	13.1	90	-4.2
210	10.1	105	-3.1
240	8	120	-2.6
270	5.2	135	-1.9
300	3.3	150	-1.1
330	1.1	165	-0.4
360	-0.4	180	0.5
390	-1.2	195	1.5
420	-3	210	3.1
450	-3.9	225	4.9
480	-4.8	240	6.1
510	-5.8	255	7.3
540	-6.9	270	8.1
570	-7.6	285	9.3
600	-12.4	300	9.5

Table 1. Freezing and Thawing Temperature measurements for 80%water+20%salt

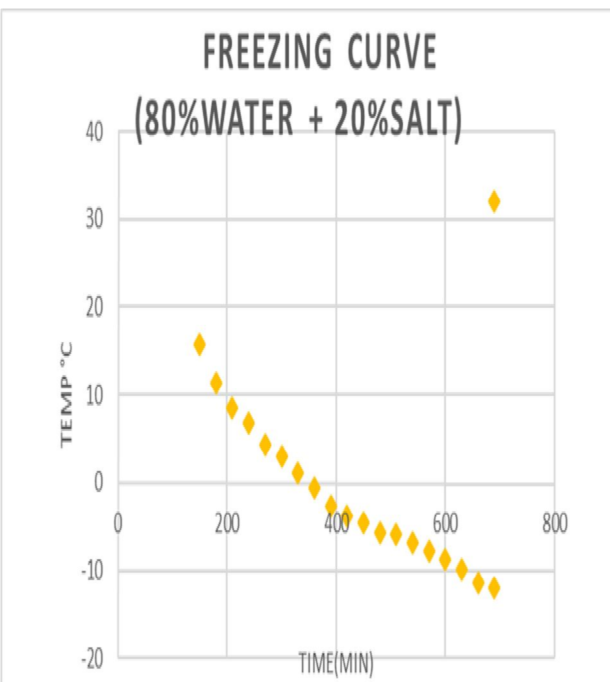


Fig 3. Freezing curve for 80%water+20%salt

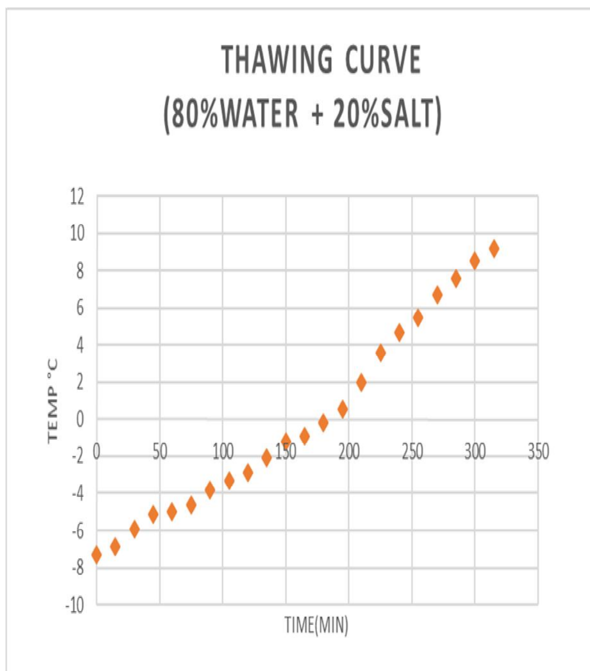


Fig 4. Thawing curve for 80%water+20%salt

From the above fig we can clear that the mixture with salt of 20% Magnesium Chloride heaxa hydrate and 80% of water will give the high freezing temperature for refrigeration.

V. CONCLUSION

The PCM Magnesium chloride hexahydrate has been used for cold storage application because of its low cost and conventional temperature of melting, soluble water to cool, which make it suitable for refrigeration application. Experimentation was performed to estimate the solidification and melting time water 80% and salt 20%. As a result, the higher thermal performances of the PCMs have proved its potential as substitute for conventional Magnesium chloride PCMs in refrigeration applications.

REFERENCES

[1] Arkar, C., Vidrih, B. and Medved, S. "Efficiency of free cooling using latent heat storage integrated into the ventilation system of a low energy building", International Journal of Refrigeration, Vol. 30, pp. 134

[2] Arkar, C., Vidrih, B. and Medved, S. "Numerical modelling of free cooling of low energy building utilizing PCM heat storage integrated into the ventilation system," in: 8th International IEAWorkshop (Annex 17), Advanced Thermal Energy Storage Trough Phase Change Materials and Chemical Reactions, Kizkalesi, Mersin, Turkey, 2005.

[3] Beasley, D. E., Ramamarayanan, C. and Torab H. "Thermal response of a packed bed of spheres containing a phase change material", International Journal of Energy Research. Vol.13, pp. 253-265, 1989.

[4] Cabeza LF, Mehling H, Hiebler S, Ziegler F. Heat transfer enhancement in water when used as PCM in thermal energy storage. ApplTherm Eng2002; 22:1141–51.

[5] Dincer, I., Rosen and Marc A. "Thermal energy storage: systems and applications", John Wiley & sons Ltd., 2002.

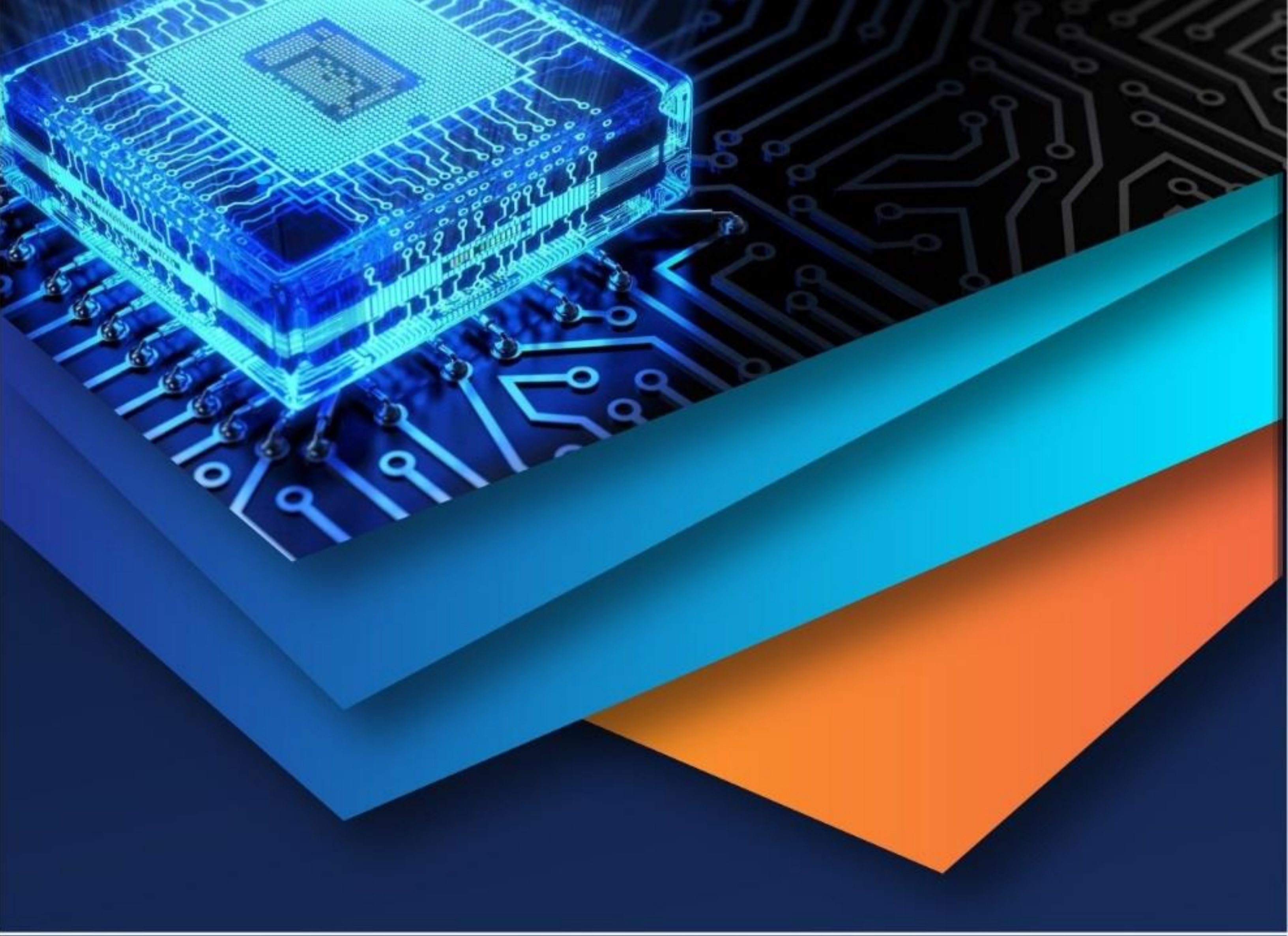
[6] Dimaano, M. N. R. and Watanabe, T. "The capric-lauric acid andpentadecane combination as the phase change material for cooling applications", Applied Thermal Engineering, Vol. 22, pp. 365-377,2002.

[7] Elgafy, A., Mesalhy, O. and Lafdi, K. "Numerical and Experimental of melting in pcm" 2004.

[8] Elgafy, A., Mesalhy, O. and Lafdi, K. "Numerical and Experimental Investigations of Melting and Solidification Processes of High Melting Point PCM in a Cylindrical Enclosure", Journal of Heat Transfer, Vol. 126, pp. 869-875, 2004.

[9] Fanny Trausel, Ard-Jan de Jong, Ruud Cuypers, "A review on the properties of salt hydrates for thermochemical storage".

[10] Farid MM, Khalaf AN. Performance of direct contact latent heat storage units with two hydrated salts. Sol Energy 1994; 52:179–89.



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